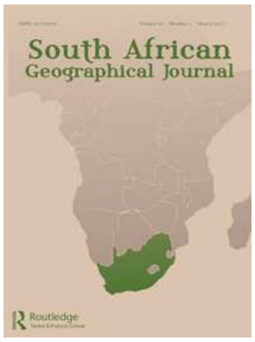

South African Geographical Journal

ISSN: 0373-6245 (Print) 2151-2418 (Online) Journal homepage: http://www.tandfonline.com/loi/rsag20

The Interactive-GIS-Tutor (IGIST): an option for GIS teaching in resource-poor South African schools

Elfrieda Marie-Louise Fleischmann & Christo P. van der Westhuizen

SOUTH AFRICAN GEOGRAPHICAL JOURNAL, 2017
VOL. 99, NO. 1, 68–85
http://dx.doi.org/10.1080/03736245.2016.1208576

The Interactive-GIS-Tutor (IGIST): an option for GIS teaching in resource-poor South African schools

Elfrieda Marie-Louise Fleischmann[a] and Christo P. van der Westhuizen[b]

[a]Geography Department, Cedar College of Education, Kranskop, South Africa; [b]Geography and Environmental Education, School of Natural Sciences and Technology for Education, North West University, Potchefstroom, South Africa

ABSTRACT

This paper reports findings from a study that examined geographic information system (GIS) knowledge development after the introduction of an Interactive-GIS-Tutor (IGIST) as a multimedia teaching tool. Although GIS has been included in the curriculum over the past decade, the majority of teachers continue to lack formal GIS training, resources, and support. As a potential solution to this problem, the IGIST offers teachers the option of using either a computer connected to a digital projector or a computer laboratory within the same application. Nine classes of grade 11 geography learners (n = 215) were selected and separated into three groups: a projector group (IP), a computer group (IC) and a textbook group (C), which also acted as the control group. After the IGIST intervention, the IP group revealed a statistically significant effect with regard to knowledge development, whereas the IC group demonstrated a significant practical effect. Participant interviews confirmed that the use of IGIST in combination with a digital projector, or within a computer laboratory, is a workable GIS teaching and learning option. Future IGIST development recommendations include providing multi-language options and more video clips with exploratory activities in Quantum GIS. This work provides a foundation upon which to expand dialogue among GIS developers, academia, teachers and the Department of Basic Education on the development of workable GIS teaching options.

ARTICLE HISTORY
Received 3 April 2015
Accepted 16 September 2015

KEYWORDS
Geography education; GIS; instructional technology; knowledge; multimedia

Introduction

Education in the twenty-first century is characterized by a learner-centred approach, and the geographic information system (GIS) holds great potential as a learner-centric teaching tool. However, most GIS teaching is focused on textbook-style teaching (Demirci, 2009), which minimizes the potential of this instructional tool that is capable of managing geospatial information through the gathering, editing, storage, conversion, analysis and visualization of geospatial data in order to perform practically any geospatial task (National Research Council, 2006). The primary aim of this paper is to present findings from a study that addressed this paradox and, secondarily, to initiate a dialogue among GIS developers,

CONTACT Elfrieda Marie-Louise Fleischmann elfriedaf@cedar.org.za

teachers, academia and the Department of Basic Education (DoBE). As such, a discussion of global GIS education is presented, followed by background context on South African GIS practice barriers that indicate the need for educational GIS applications. After various GIS instructional approaches are considered, development of the Interactive-GIS-Tutor (IGIST) application is discussed. Using an explanatory research design, based on the theoretical framework of pragmatism, we evaluated the impact of the IGIST on knowledge development while comparing the bimodal use of the projector and computer. This paper concludes with recommendations for future IGIST development and research.

Global GIS educational background

Because of the potential positive impact of GIS on geography instruction, there has been a global move to include it in school curricula. However, due to the lack of user-friendly curriculum-orientated GIS software that is affordable, required computer hardware and teachers' GIS teaching knowledge, the integration of GIS into instructional practice has stalled. Unlike countries such as Austria, Canada, Ghana, India and New Zealand that struggle to integrate Internet and computer use in the classroom setting, countries like Denmark, Finland, Japan and the UK are well-equipped to utilize GIS resources. Yet all these countries, and others, have in common the under-utilization of GIS in instructional practice (Kerski, Demirci, & Milson, 2013). Several factors impact teachers' under-utilization of GIS. A marked hesitancy amongst geography teachers, even in technologically advanced countries, may reflect an *underlying teacher uncertainty about how to maximize the benefits of GIS in classroom instruction* (National Research Council, 2006). Second, teachers may be constrained by *limited available time* required to become familiar with and implement complex GIS software (Baker, Palmer, & Kerski, 2009). The overall complexity of GIS software demands extensive professional teacher development and technical preparation (Baker, 2005), as well as additional instructional time. A third hindrance is the lack of *curriculum-orientated GIS materials* among a wide array of GIS educational software possibilities (Chun, 2008). Fourth, shortages in a combined educational and geospatially skilled workforce hinder the future development of pre-built GIS curriculum-centred educational media. Furthermore, research has shown that even highly trained and qualified GIS tutors prefer to use pre-built GIS media that include data, learner materials and assessment tools (Baker et al., 2009). These and other factors relevant to pedagogical and software issues emerge as prominent barriers to effective instructional utilization of GIS. These findings coincide with multi-level barriers encountered by Taiwanese teachers who reported their lack of confidence in manipulating GIS software, citing the need for suitable GIS educational software and professional development/training (Wang & Chen, 2013). Moreover, dissimilar physical surroundings, especially when considering South Africa's digital divide, impact the effectiveness of GIS teaching methods. Therefore, South Africa's unique educational and environmental challenges must be taken into account when considering new GIS educational endeavours.

GIS education and challenges in South Africa

Global trends regarding GIS implementation are evident in South Africa. Although GIS is included in the South African Curriculum and Assessment Policy Statement (CAPS), the

South Africa Department of Basic Education (DoBE, 2011a) has reported multifaceted GIS implementation challenges, such as little support from school leadership, school communities and local tertiary institutions, government and industry (Breetzke, Eksteen, & Pretorius, 2011) as well as resource shortages. As a result of the failure to employ GIS practice in the school setting and a wide array of GIS integration hurdles, educators have succumbed to the use of 'paper GIS' as espoused in the CAPS document of 2011. However, some South African schools possess computer and/or projector facilities, making possible an examination of South Africa's GIS practice integration problems in order to further GIS instruction in the classroom setting. Moreover, Britz and Webb's (2014) study of South African learners found that GIS software and geospatial data promotes spatial cognition among this population. It is thus our intention to evaluate the use of an Interactive-GIS-Tutorial application in the area of knowledge development required by South African curriculum.

The digital divide

The digital divide in South Africa (SA) is notable, and the gap is widening (Brown & Czerniewicz, 2010). These scholars characterize this divide according to variations in information communication technology familiarity and experience (caused by inequalities of digital access and opportunity) rather than the age of the consumer. This inequality between the 'haves' and the 'have-nots' is pervasive throughout the South African education system, thus impacting GIS teaching. For example, the 2011 *National Educational Infrastructure Management System* report stated that only 2489 of the 24,793 public South African schools (10%) have been equipped with computers in a computer lab (South Africa DoBE, 2011b). Apart from the inadequate resources found predominantly in rural and urban poor schools, deficient school community support and teacher time constraints remain key GIS integration constraints (Breetzke et al., 2011). The South African education sector faces the additional challenges of accommodating 11 official languages as well as a wide spectrum of economic levels and academic proficiencies. These challenges contribute to the difficulty in achieving the United Nations' international GIS education standards. Despite SA's unique multi-level GIS educational challenges, the DoBE is committed to 'promot[ing] the generation of new electronic content that is aligned with outcomes-based education' (South Africa Department of Basic Education, 2004, p. 28). Nonetheless, addressing the problem of 88% of schools that lack educational tutorial software in all subject areas (as compared to 54% of schools in the developing country of Chile) entails strenuous efforts (Blignaut, Hinostroza, Els, & Brun, 2010). Moreover, the shortage of computer-literate geography teachers, especially among veteran teachers who most often head schools' geography departments, and the large number of teachers who lack computer access for teaching and learning purposes further hinders the efforts of both the DoBE and school teachers (Britz & Webb, 2014; Innes, 2011). In this respect, a limited number of local programmes and organisations are committed to the development of digital content for use in South African schools in order to address educational needs.

The curriculum and GIS practice

During 2006, the DoBE launched the integration of GIS as a section of the Grade 10 geography syllabus (Scheepers, 2009) and re-embraced GIS in the CAPS document of 2011

(South Africa DoBE, 2011). In practice, however, minimal GIS integration has occurred since introduction into the curriculum (Scheepers, 2009). In fact, GIS practice implementation in South Africa has stalled due to the same challenges faced by Hungary, Lebanon, Rwanda, Finland and Columbia, which include teachers' lack of GIS knowledge and skills, lack of lesson preparation time and the need for pedagogical guidance (Kerski et al., 2013). Although it was anticipated that GIS instruction would enhance the reputation of geography within a school's curriculum (Rød, Larsen, & Nilsen, 2010) and clarify the role of geography within academia globally (Oberle, Joseph, & May, 2010), observers such as Mini, (as referred to by Innes (2011) and Britz and Webb (2014) differ in their views of GIS education within SA. However, despite implementation barriers and delayed integration of GIS into classroom practice, it should be noted that some geography teachers from both public and private sectors situated in rural and urban areas await a viable and workable GIS application, along with integration guidelines (preliminary results from a 2015 nationwide GIS teacher survey, conducted by the authors). For these teachers, an IGIST approach may serve as a 'GIS-gateway' to more advanced GIS, which could, in turn, result in progress towards more complex, industry-driven GIS software, thus fostering a GIS skilled work force.

We affirm Baker and Bednarz's (2003) position regarding GIS research. More than a decade ago, these scholars argued that unless methodologically sound GIS educational research was undertaken to address research gaps, it was doubtful whether GIS practice would flourish within the education systems. In the light of the aforementioned challenges hindering the advancement of GIS education, there is an urgent call for South African research in this field.

Solutions within a South African context

Although GIS practice in SA education has faltered, there are some GIS teaching avenues available, such as:

- A paper-based GIS initiative, managed by ESRI South Africa (Pty) Ltd, envisages the introduction of GIS to resource-poor (without electricity and/or computers) schools in South Africa (Breetzke et al., 2011; Kerski et al., 2013). Although this praiseworthy effort aims to enhance GIS teaching in these schools, the authentic potential of GIS can only be unlocked when learners and teachers are able to utilize available digital GIS platforms, such as ArcView 3.3, Quantum GIS (QGIS) and Web-based software. Therefore, outcomes are limited because of the lack of such platforms.
- Sponsored by the Department of Land Affairs (DLA) in the Eastern Cape in South Africa, QGIS is a free, downloadable and open-source software product that includes 'A Gentle Introduction to GIS' user manual. This manual guides the educator and learner through a series of worksheets. Although the manual provides guidance, it may also create a split-attention effect, obstructing constructive learning (Mayer & Moreno, 2003). Various low-quality YouTube videos (on the theme 'Gentle introduction to GIS' produced in 2010 by Chief Directorate: Spatial Planning and Information, DLA of the Eastern Cape) are also available, providing mini-lectures on the use of QGIS.
- Benefits of using Web-based GIS are maximized when complex and unused features of desktop GIS are minimized, thereby enhancing the ease of GIS learning (Baker, 2005) and increasing interactive learning. For example, Web-based GIS has been

successfully used as a public participatory GIS to enhance the active engagement of communities (Eisner et al., 2012). Virtual globe features, such as Google Earth, are popular for visualizing information (Goodchild & Janelle, 2010). Released in 2005, Google Earth has the capacity to encourage and motivate learners in using geospatial technology in everyday life (Doering & Veletsianos, 2007). However, large data file sizes require a fast broadband connection (National Research Council, 2006), which is not always available in South African schools. Nevertheless, because of recent Internet connectivity advances, Web-based GIS might flourish in these environments in the near future.

- ArcOnline allows users to combine their proprietary data with data readily provided by ESRI in order to create web maps. During 2014, ESRI-USA offered a free ArcGIS online subscription to every US K-12 school. Although this offer was not extended to South Africa, widening bandwidths and increased Internet availability might pave the way for standardized ArcOnline GIS education in the future.

Global diffusion of GIS practice into education remains a confounding and challenging issue. While few SA schools possess a reliable Internet connection, a self-paced interactive GIS plug-and-play tutor application might overcome teaching–learning barriers. Such a tutor application may prove to be a viable anytime-anywhere learning option, supporting immediate GIS learning and teaching needs. Furthermore, such an application that can be used without a learner guide would also lessen the split-attention effect caused by learner guides as in the case of QGIS and ArcView 3.3.

The Interactive-GIS-Tutor

The IGIST has been developed to address the context specific multi-level challenges of GIS education by providing a curriculum-aligned GIS application. Moreover, the IGIST has been designed to address the lack of GIS teacher training and limited GIS pedagogical skills. A digital projector attached to a laptop computer could be used to support GIS learning in schools without functioning computer labs. The IGIST, stored on a flash drive stick, can support anytime-anywhere learning.

Development of the IGIST

Development of the IGIST was a combined effort by the GIS Department and the Geography Education Department of North-West University (NWU). The vision of these departments was to develop self-paced interactive tutorial software that could circumvent major GIS practice barriers, including teachers' lack of GIS knowledge and complex use issues, while supporting the individual learning process. During the IGIST development, QGIS and Adobe Captivate 5.5 were used to create tutorials and exercises as well as assessment tools. The GIS process was executed in QGIS software, while Captivate recorded the process in the background. These recordings were then compiled into an executable (*.exe) file format compatible with most computers. When opening the files, the user encounters captured screenshots (created in QGIS) that provide simulations. An introduction, three tutorials, four exercises and two multiple-choice assessments were created. These IGIST activities take approximately 90 min to complete in one sitting, but they can also be administered over

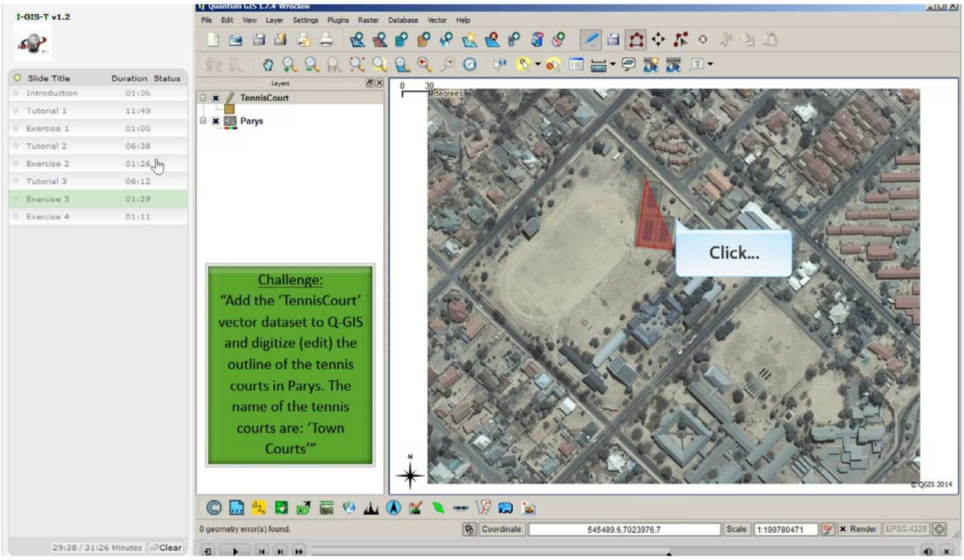

Figure 1. Screenshot of IGIST learner interactivity and audio-visual guidance within an exercise. (Source: Author).

three or four periods in order to accommodate slow learners who require more practice and reviewing of the activities. Because the IGIST application is a self-paced, interactive, multimedia tutorial with review (redo) options, the learner remains in charge of his/her own learning. The IGIST application can serve as a gateway to the real QGIS program.

Tutorial 1

Tutorial 1 was compiled from 136 screenshots, each being reviewable. The opening scene of this tutorial displays the outcomes of the tutorial.

Thereafter, a description of the what, where, how, who and why questions regarding GIS, along with problem solving options, follows. The QGIS features are described in the subsequent sections, followed by a discussion of how to save a map file. Finally, the outcomes are revised and an invitation extended either to review the tutorial or to progress to Exercise 1, which can be selected from the main menu.

Exercise 1

Exercise 1 is relatively short, with 16 screenshots, in comparison to the other IGIST activities. Upon beginning this exercise, a screen appears depicting the expected outcomes of the exercise. Within this exercise, skills gained during Tutorial 1 are practised, as seen in Figure 1.

For assessment purposes, this exercise consists of three multiple-choice quizzes as well as multiple opportunities to retake the quizzes. The assessments are designed to accommodate various academic levels and provide immediate feedback to learners' responses to question items. The entire exercise consists of 13 reviewable screenshots, which conclude with the option for the learner to repeat the exercise or advance to the tutorial, which is displayed in the main menu.

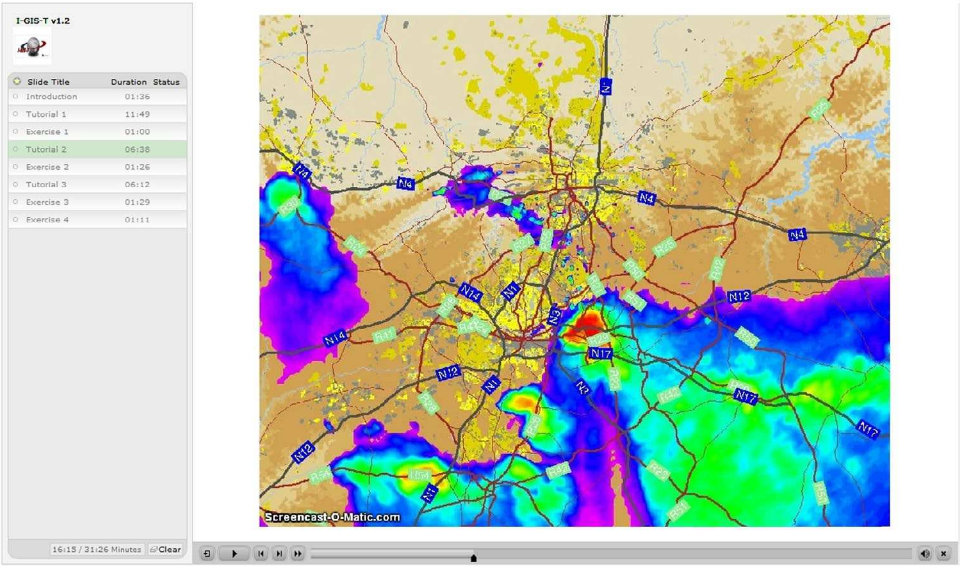

Figure 2. Screenshot of video demonstrating the use of remote sensing in a hail storm.

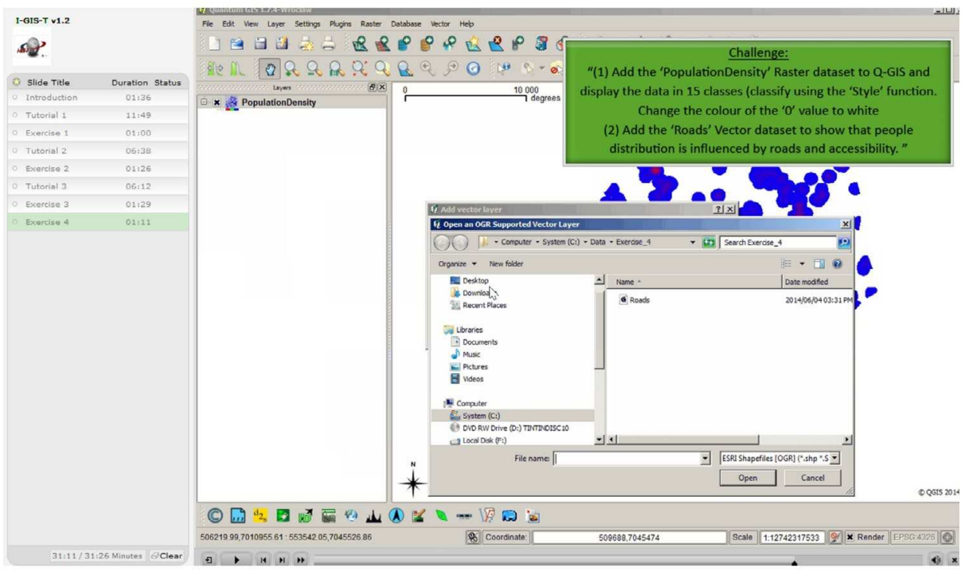

Figure 3. Screenshot of I-GIS-T activity challenge taken from Exercise 2.

Tutorial 2

Tutorial 2 begins with an outcomes screen (text) depicting the outcomes to be achieved by the end of the tutorial. Thereafter, various real-life uses of GIS are displayed, followed by the use of remote sensing to investigate and monitor hailstorm activity spectral analysis (Figure 2). Next, the differences between raster and vector data are described since both types of data are employed and a raster calculator is utilized within this investigation.

Figure 4. Computer IGIST intervention group. (Source: Author).

The tutorial investigation consists of interactive features whereby the learner is guided step-by-step with narration and animated guidance. Tutorial 2 is divided into 76 reviewable screenshots and is designed for self-paced learning. This activity concludes with a review of the outcomes and the option to repeat the tutorial or advance to Exercise 2.

Exercise 2

At the beginning of Exercise 2, a screen appears depicting the expected outcomes of the exercise. Thereafter, skills learned in Tutorial 2 are practiced. Exercise 2 consists of 22 screenshots that the viewer can navigate between and concludes with the option to repeat the exercise or advance to Tutorial 3 (Figure 3).

Empirical investigation

Preceding this study, a pilot run of the IGIST application showed that the IGIST was successfully used in a single class, and it was recommended that a further empirical investigation be conducted with multiple classrooms (Fleischmann, Van der Westhuizen, & Cilliers, 2015).

Research design and methodology

The aim of this study was to compare the GIS knowledge development of learners who used the IGIST applications via a projector or computer in large classes with the knowledge development of learners who received textbook GIS instruction across seven multi-cultural urban poor[1] or rural SA schools. The chosen methodology was tailored to provide a synergistic view of the evidence in order to enhance an in-depth understanding of the complex nature of GIS practice integration. In order to test whether the IGIST application promoted GIS learning, a quasi-experimental design with pre- and post-knowledge tests was used, followed by learner focus groups and teacher interviews. The study sample included two interventional groups (IC and IP) as well as a control group (C).

Seven schools were selected as research sites based on the ability to access them during the study period (availability sampling). The schools are situated within the rural and urban poor area of KwaZulu-Natal Province, and their student enrolments included learners from different socio-economic and cultural backgrounds who spoke diverse home languages. Pseudonyms were assigned to schools, teachers and learners and used throughout the study to ensure anonymity. Based on the availability of workable computers and a digital projector, the schools were divided into a computer group (IC), a projector group (IP) and a control group (C). The computer group (IC, n = 60) comprised three classes from Duncan High (n = 19), Valken Hoërskool (n = 14) and one Standard Secondary School class (Sa, n = 27). The projector group (IP, n = 65) comprised Glenville High (n = 31), Vumeze High (n = 16) and Houston High (n = 18). Lastly, the control group (C, n = 90) consisted of Wycliffe High (n = 25) and two classes from the Standard Secondary School (n = 31 and n = 34). The geography teachers (n = 6) of the intervention group (both IP and IC) who were interviewed after the intervention had between 3 and 32 years of geography teaching experience. The pre-knowledge tests (performed before the intervention) were conducted on 215 learners with tabled results.

Instrumentation, data-collection and analysis

Two main strategies were used to collect data from research participants: (i) pre/post knowledge tests and (ii) learner focus groups and teacher interviews. The pre- and post-knowledge tests included both low and higher order knowledge, in keeping with Bloom's taxonomy as used by West (2003, p. 268) for GIS teaching. Moreover, the tests were designed to measure the Curriculum Assessment Policy outcomes for grade 11 learners. The pre- and post-tests (multiple-choice format) consisted of the same questions and answers, but they were shuffled. After the IGIST intervention activities, seven semi-structured learner focus groups and six semi-structured teacher interviews were conducted.

Data analysis

Analysis of data consisted of descriptive statistics, such as frequencies, means, standard deviations and effect sizes. The dependent t-test was employed to determine the change in knowledge between the pre- and post-test. Effect sizes and Cohen's d-values, reflecting the importance of the observed effect in practice, were also calculated. A quasi-experiment was conducted in order to investigate the extent of knowledge development attained through the utilization of a projector in comparison to computers and a control group, which received textbook teaching. The data gained from this quasi-experiment represent scores collected on grade 11 learners in different classes within the three main groups. Due to the fact that learners in the same class cluster may have something in common, the authors reasoned that it is incorrect to make the usual assumption that observations are independent; therefore hierarchical linear modelling (HLM) was used. The primary independent variable was the intervention (use of IGIST): a three-level intervention whose categories consist of the projector group (IP), computer group (IC) and a control group. All learners in the same class had the same intervention value, so the treatment was determined to be a level-two variable. Models of post-intervention scores also controlled for learner level (that is, level-one) scores on the pre-test. The NWU's Statistical Consultation Services assisted with data analysis and interpretation of quantitative data. Qualitative analysis of interviews was performed by means of the use of ATLAS.ti7™. Inductive coding as well as deductive coding methods were employed.

Ethical aspects and trustworthiness

Permission to conduct this study was granted by NWU and the KwaZulu-Natal Department of Education. Principals and study participants provided informed consent and participation took place on a voluntary basis. Confidentiality was assured. Content validity (to establish if the measure covers the variety of meanings within a concept) was verified by the head of the project while the NWU Statistical Consultation Services checked knowledge tests for face validity. A peer coder and a peer auditor were employed to verify the qualitative coding and findings.

Findings and implications

Descriptive statistical analysis of knowledge tests

The knowledge tests consisted of 20 multiple choice questions with 5 options per question to test the learners' GIS knowledge before and after the interventions. These questions were focused on content and conceptual knowledge as stipulated within the CAPS curriculum document. Questions included the spectrum of both lower and higher order questions. Lower order questions included basic knowledge of GIS, such as 'what is resolution?', whereas higher order questions included application questions on choice of map layers for given scenarios, such as 'the spread of wild fires'. The face value of the questions was verified by a lecturer and editor of grade 10 and 11 geography textbooks from NWU. The sequence of possible answers was shuffled for the post-test in comparison to the pre-test. The Cronbach's α score of .52, although on the low side, was acceptable within the context of this study. A possible reason for the relatively low, but acceptable value, is that the higher order questions could not be answered by merely recalling the IGIST application tutorials and therefore the learners experienced them as difficult. However, the answers to these questions were considered important to this study. Although the inclusion of procedural knowledge-based questions could have resulted in a possible higher Cronbach's α score, procedural knowledge is not referred to in the CAPS curriculum document, and was therefore not included.

Analysis of knowledge by means of HLMs

Since the learners were not randomly selected, but rather selected according to classes, it cannot be assumed that observations are independent as assumed with most traditional statistical analyses. Results from learners in the same school (or SES) could be assumed to be dependent and, therefore, HLM with school as primary unit of measurement were performed.

Description of group differences before intervention

The pre-test results of the three groups were analysed to check for between-group differences before the IGIST intervention. The pre-knowledge tests revealed that all three groups were similar regarding GIS knowledge, with no practical significant differences regarding GIS knowledge, as verified by effect sizes indicated in Table 1.

Table 1. Comparison of control and intervention groups during pre-test with HLM.

	Mean (%)	Std. error	*p*-Value	Effect size control with	Intervention computer with
Control group	39.7	4.6			
Intervention computer	40.7	4.7	.905	.006	
Intervention projector	42.6	4.7		.014	.12

Note: Dependent variable: knowledge pre-test.

Development of knowledge after intervention when corrected for pre-test differences

The mean percentage of IP (66.4) was found to be much larger than both C (34.5) and IC (46.1) as shown in Table 2. Comparing the effect size of the IP group, we discovered a large effect size in comparison to C (1.56) and IC (.99). The IC group also achieved higher scores than C in practice with an effect size of .57.

Statistically and practically significant differences were found in the post-knowledge tests between the three groups (see Table 3). Table 3 records the main school groups as well as each factor's results. Although the effect size is usually reported as the absolute value of the standardized differences, we chose to report the sign in this case to indicate the direction of knowledge development. A negative sign indicates a lower post-knowledge score, whereas a positive sign indicates an increase in knowledge. *The IP group* demonstrated a positive growth in knowledge with effect sizes for Glenville High (1.86), Houston High (.58), and Vumeze High (4.06).

In the IC group, Duncan High demonstrated a positive growth in knowledge ($d = 1.36$), whereas the other two classes gave no significant indication of change in knowledge. In *the C group*, the two classes from Standard Secondary School, class S11b (−.92) and S11c (−.57) both reflected a decrease in knowledge, whereas Wycliffe gave no significant indication of change in knowledge.

Inferences drawn from knowledge test results

Surprisingly, the IP group showed an overall highest effect size with regard to knowledge. This could be due to the fact that the intervention class (Sa) of Standard Secondary School belonging to the IC group received just a 2-h session on the computer, which was due to teacher union strikes. Furthermore, the teachers of Valken Hoërskool informed me that the learners did not take the post-test seriously, as they *would not get anything out of it*. Under normal circumstances, these results could be expected to be higher in the IC group. Valken Hoërskool was the only school where a slack attitude was observed or reported

Table 2. Comparison of control with intervention groups with post-test with HLM.

	Mean (%)	Std. error	*p*-Value	Effect size C with	IC with
Control group	34.5	.070			
Intervention computer	46.1	.071		.57	
Intervention projector	66.4	.071	.049*	1.56	.99

Note: Dependent variable: knowledge post-test.
*$p \le .05$.

Table 3. Paired samples knowledge tests statistics of the various groups and classes.

Grouping	School (pseudonyms used)	Knowledge test	Mean	*N*	Standard deviation	Sig. (2-tailed)	Effect sizes
Intervention: IGIST by means of projector/ whiteboard (IP)	Glenville High (G)	Pre	.3643	31	.14362	.000***	1.86
		Post	.6319	31	.15561		
	Houston High (H)	Pre	.5392	18	.14584	.016*	.58
		Post	.6242	18	.17489		
	Vumeze High (Vu)	Pre	.3787	16	.09598	.000***	4.06
		Post	.7684	16	.08717		
Intervention: IGIST by means of the computer (IC)	Duncan High (D)	Pre	.4582	19	.14352	.000***	1.36
		Post	.6533	19	.19000		
	Standard Secondary (Sa)	Pre	.3464	27	.14066	.720	−.14
		Post	.3268	27	.21417		
	Valken Hoërskool (V)	Pre	.4202	14	.17244	.836	−.05
		Post	.4118	14	.17722		
Control group (C)	Standard Secondary (Sb)	Pre	.3833	31	.12327	.017*	−.92
		Post	.2694	31	.20590		
	Standard Secondary (Sc)	Pre	.3235	34	.10666	.060	−.57
		Post	.2630	34	.14785		
	Wycliffe High (W)	Pre	.4871	25	.20272	.542	.08
		Post	.5035	25	.17572		

*$p \leq .05$.
***$p \leq .001$.

during the tests. Interestingly, all the classes within the IP group displayed a statistical and practical significant growth in effect sizes. Vumeze High, in particular, gave indications of the greatest increase in knowledge development with an effect size of (4.06). Vumeze High is situated in a rural area with few available resources, and Vumeze High learners, who are not familiar with multimedia learning opportunities, were highly interested in the IGIST. Because learners are no longer accustomed to studying on their own, they might be less anxious when learning together in a group, as in the case of the IP group. In addition, some learners in the IC group, because of limited computer skills, experienced anxiety that hindered their learning. These suggested explanations were followed up during the interview phase of the study.

Qualitative results from learners and teachers' perspectives

The interview transcripts were gleaned for quotes supporting the development of GIS understanding, as well as quotes indicating a lack of learning. After the IGIST intervention, a majority of 28 quotes supported this development, whereas only one quote from a Houston High learner suggested no learning, resulting from a technical problem. Reasons for positive understanding of GIS were: (a) the visual displays enhanced user understanding, (b) the practical activity was decisive in enhancing user understanding and (c) the repeat/review option within the IGIST activities provided immediate pedagogical support. Table 4 displays a comparative matrix summary of qualitative findings from this multiple case study, enabling contextualization, comparison and discussion of each of the settings.

Table 4. Comparison matrix summary of six intervention classes.

Intervention group	School	Learner's perspectives on GIS knowledge development	Teacher's perspectives on GIS knowledge development
IP	Glenville High (G)	• Learned a lot and described the IGIST as helpful guiding their learning	• Learners better understood the GIS concepts, as they could interact with the software
	Houston High (H)	• Learners preferred working on a computer rather than through a projector, but did state that they did gain new knowledge and found the IGIST interesting	• Felt distracted when making the switch from IC group to IP group; (computers were not functioning, and therefore a projector was employed during the lesson)
	Vumeze High (V)	• Very positive regarding the IGIST application, gained knowledge and directive towards future career choices	• Learners were concentrating on the lesson, and remained focussed all the time during the activity
IC	Duncan High (D)	• Mentioning of the redo function, enhancing their learning, although one learner said the tutorial was too fast	• The IGIST enhanced GIS understanding and created an atmosphere of learning
	Standard Secondary School (S)	• Stated that they learned much from the IGIST activities although wish for a game to be included in the program	• The learners understood better, viewing the images and listening to the audio cues
	Valken Hoërskool (V)	• Good feedback from learners, although they requested that the narrator need to explain more why certain buttons need to be chosen	• Learners remained focused while on computers, and definitely gained new GIS knowledge

Note: Pseudonyms were used.

IP group

Regarding GIS knowledge development in the projector group, a learner from the Glenville learner focus group clarified that 'the IGIST explains a bit more; because you actually see everything happening, I understood it a bit better than the textbook'. Other members of the focus group also affirmed that the IGIST did enhance learning. One learner explained, 'the only thing that I knew about GIS was that it's a geographical information system, and that it consists of a vector and a raster data … , so we learned a lot … it was very helpful'. The members of the Glenville learner focus group all claimed that the IGIST application enhanced their understanding of GIS more than textbook teaching and stated that 'it was good; I enjoyed the challenge because you actually, learnt stuff while doing it, and it was fun to just learn new stuff, stuff we didn't know'. A learner from Houston High affirmed this notion stating 'I really enjoyed this GIS program. It really helped me to see things in real life. It was such a good learning program. Hopefully we will get another chance to do this GIS program'. Another learner from the same school declared 'it has been interesting. It has kept me engrossed and wanting to know what comes next'. Some learners also recognized the use of GIS in their future career, as one learner from Vumeze High described:

> I even learned that in order to become a meteorologist, you need GIS … these exercises helped me a lot and … this has shown a clear picture of what GIS is and why it is used … described job opportunities that I didn't know that they use/need GIS.

Mr Green observed in his class that 'kids find it easier to understand with words associated with pictures … the way IGIST explains it as well, the kids have a better understanding and concept'.

In summary, based on the qualitative data, we assert that the teachers and learners from the IP groups in this study were to a large extent positive in their agreement that the IGIST enhanced conceptual understanding and learning of GIS.

IC group

In the IC group, Valken Hoërskool learners explained that after the IGIST activities:

> you start to understand how GIS actually comes into your day to day life and I did learn a lot; … I never knew there's a lot of … sub categories underneath GIS, like raster data and spatial data and all that stuff, I've never heard of that.

This notion was supported by learners of Standard Secondary School focus group who remarked, 'it's very understanding … I gained a lot of skills. It really changed my understanding of things … it is a great exercise to do … GIS is very interesting and cool'.

The Duncan learner focus group explained that 'it's nice because you can go and redo it again until you get it right, as you continue, you improve, and get much better, and understand it much better'. However one learner from Duncan High found the 'tutorial too fast and complained that [it] did not explain [each of] the procedures with enough detail'. This was taken note of and referred back to the developer of the IGIST application (Figure 4).

From a teacher's viewpoint, Ms Duma observed that:

> GIS without this tutorial can be very boring and theoretical. I think sometimes the learners don't quite understand what it's about. But with this [IGIST], they can understand what it's about and they enjoy working with it, so it creates that atmosphere of learning.

As for reasons why Ms Duma felt that the IGIST impacted GIS knowledge, the practical nature and active learning supported by the IGIST enhanced the understanding of abstract GIS concepts. Moreover, Mr Sanger explained, 'I think they understood better by seeing images and the, you know, visual, and audio cues telling them what to do'. In addition, Ms Venter observed that the IGIST kept the learners intrigued and noticed an increase in their attention span: 'down there in the computer lab, they actually didn't comment to each other all the time, which is very unusual for them … they were focusing on what they were meant to be doing'. In summary, qualitative findings indicate that the teachers and learners from the IC groups, to a large extent, affirmed that the IGIST enhanced the learners' conceptual understanding and learning of GIS.

Implications of the IGIST application in educational GIS practice

The pre- and post-tests results came as a surprise to the authors, because it had been anticipated that the computer group would reflect the highest scores with regards to knowledge development. However, the data from this study might confirm the findings of Demirci (2011, p. 57), which showed that the single-computer classroom group fared better than the computer library group. Therefore, the data from this study might be indicative that grade 11 geography learners within a rural or urban poor resourced environment, are used to learning within a group context because of their experiences of 'Ubuntu', which involves shared experiences (Muwanga-Zake, 2007). Secondly, the projector group also underwent more teacher (i.e. direct instruction) input, when compared to the computer group. Furthermore, the advent of social media, whereby learners tend not to work in isolation on a task might explain why the computer group did not excel as expected. Although the IGIST application circumvented network Internet bandwidth and low computer memory problems by being stored on a USB flash drive, thereby requiring only a USB port, schools in rural and poor urban areas do not always possess any, or enough, workable computers for all learners. In addition, issues such as computer viruses and lack of sound cards were found to be problematic at some of these schools. Furthermore, it was our observation when regularly visiting these schools, that geography classes within rural and urban poor areas may be comprised of as many as 50 or more learners per class who often have a poor English understanding of abstract GIS concepts. In such a context, IGIST activities by means of a projector remain an especially valuable solution for GIS practice integration within grade 10–12 geography classes. Therefore, the IGIST application might be an adaptable, cost-effective and versatile application to support teachers who require additional instructional tools for teaching abstract GIS concepts within schools with few resources. As previously indicated, some teachers also struggle to teach GIS due to a lack of formal training, as the following teacher interview comments reveal: '*in the sense that at the moment I don't really want to* [teach GIS] *because I feel it's a huge mountain, and I feel intimidated because I don't know enough*'. The IGIST multimedia application, however, was well received by teachers attending a workshop: 'it is an excellent tool to promote the understanding and implementation of GIS in our schools so that it can achieve its desired goals' and 'the best of the material that I have tried since GIS was first introduced'. In addition, the majority of the teachers within this study mentioned that they would be interested in running IGIST workshops in their clusters.

Conclusion and recommendations

Based on the findings of our study, it is possible to conclude that the projector group, which demonstrated a significant enhancement of knowledge and understanding, may be a suitable avenue for GIS teaching in rural and poor urban schools in South Africa. As learners from poorly resourced schools do not have many opportunities to work with computers, many may experience computer anxiety, which might impair their learning (Bozionelos, 2004; Simsek, 2011). However, learners from both the projector and computer groups described the IGIST as suitable for enhancing GIS learning. The teachers also experienced the IGIST activities, from both the projector and computer mode, as a viable solution for circumventing their main GIS practice barriers, such as pedagogical uncertainty, limited time to prepare lessons, lack of funds for computer labs and the lack of curriculum-orientated GIS materials. Teachers from both the projector and computer groups felt that the IGIST not only enhanced the learners' GIS understanding, but also their own understanding. However, these judgements must be balanced by teacher motivation, curriculum time constraints and support. Nevertheless, findings from this research contribute to the debate on South African GIS teaching modes and applications.

Further research into the performance of the IGIST application in both typical and atypical settings should be conducted. Moreover, a cross-case study that includes cases from various developing countries with similar GIS practice challenges and needs might provide more insight into the workability and viability of the IGIST within the internationally developing countries' GIS educational landscape. On the basis of the promising findings presented in this paper, work on the remaining issues, such as attitudinal development and GIS teaching barriers, is continuing and will be presented in future papers. We invite all shareholders to take part in this discourse.

Note

1. Schools that struggle to obtain school fees from learners, and therefore experience difficulties in school maintenance, and low resources such as non-available or broken computers.

Acknowledgements

The authors would also like to acknowledge the Faculty Natural Sciences: School of Sciences and Development of North West University (NWU), South Africa and for development of the IGIST as well as the Geography Education subject didactics specialist of NWU for pedagogical aligning IGIST.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the NRF [88893]. The Dean's Prestige PhD bursary from NWU Education also funded this research [10650997].

ORCID

Elfrieda Marie-Louise Fleischmann http://orcid.org/0000-0002-0918-0226

References

Baker, T. (2005). Internet-based GIS mapping in support of K-12 education. *The Professional Geographer, 57*, 44–50. 10.1111/j.0033-0124.2005.00458.x

Baker, T., & Bednarz, S. W. (2003). Lessons learned from reviewing research in GIS education. *Journal of Geography, 102*, 231–233.

Baker, T., Palmer, A., & Kerski, J. (2009). A national survey to examine teacher professional development and implementation of desktop GIS. *Journal of Geography, 108*, 174–185. 10.1080/00221340903435934

Blignaut, A. S., Hinostroza, J. E., Els, C. J., & Brun, M. (2010). ICT in education policy and practice in developing countries: South Africa and Chile compared through SITES 2006. *Computers & Education, 55*, 1552–1563.

Bozionelos, N. (2004). Socio-economic background and computer use: The role of computer anxiety and computer experience in their relationship. *International Journal of Human-Computer Studies, 61*, 725–746.

Breetzke, G., Eksteen, S., & Pretorius, E. (2011). Paper-based GIS: A practical answer to the implementation of GIS education into resource-poor schools in South Africa. *Journal of Geography, 110*, 1–10.

Britz, H. W., & Webb, P. (2014). The effect of an intervention using GIS-generated geo-spatial data on the promotion of spatial cognition and spatial perspective taking in grade 11 learners. *South African Geographical Journal*, *98*, 1–12. 10.1080/03736245.2014.977815

Brown, C., & Czerniewicz, L. (2010). Debunking the 'digital native': Beyond digital apartheid, towards digital democracy. *Journal of Computer Assisted Learning, 26*, 357–369. 10.1111/j.1365-2729.2010.00369.x

Chun, B. A. (2008). *Geographical perspectives strengthened by GIS in an interdisciplinary curriculum: Empirical evidence for the effect on environmental literacy and spatial thinking ability* (Doctor of philosophy). New York: State University of New York (3320481).

Demirci, A. (2009). How do teachers approach new technologies: Geography teachers' attitudes towards geographic information systems (GIS). *European Journal of Educational Studies, 1*, 43–53.

Demirci, A. (2011). Using geographic information systems (GIS) at schools without a computer laboratory. *Journal of Geography, 110*, 49–59. 10.1080/00221341.2011.532563

Doering, A., & Veletsianos, G. (2007). An investigation of the use of real-time, authentic geospatial data in the K-12 classroom. *Journal of Geography, 106*, 217–225. 10.1080/00221340701845219

Eisner, W. R., Jelacic, J., Cuomo, C. J., Kim, C., Hinkel, K. M., & Del Alba, D. (2012). Producing an indigenous knowledge web GIS for Arctic Alaska Communities: Challenges, successes, and lessons learned. *Transactions in GIS, 16*, 17–37. 10.1111/j.1467-9671.2011.01291.x

Fleischmann, E. M., Van der Westhuizen, C. P., & Cilliers, D. (2015). Interactive-GIS-Tutor (IGIST) integration: Creating a digital space gateway within a textbook-bound South African Geography class. *International Journal of Education and Development using Information and Communication Technology, 11*, 23.

Goodchild, M. F., & Janelle, D. G. (2010). Toward critical spatial thinking in the social sciences and humanities. *GeoJournal, 75*, 3–13. 10.1007/s10708-010-9340-3

Innes, L. M. (2011, May). The South African school geography classroom: potential nursery for local tertiary GIS education. In *Presentation at AfricaGEO Conference: Developing Geomatics for Africa* (Vol. *31*). Cape Town, South Africa .

Kerski, J., Demirci, A., & Milson, A. J. (2013). The global landscape of GIS in secondary education. *Journal of Geography, 112*, 232–247.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist, 38*, 43–52.

Muwanga-Zake, J. (2007). Introducing educational computer programmes through evaluation: A case in South African disadvantaged schools. *International Journal of Education and Development using ICT, 3*, 30–48.

National Research Council. (2006). *Learning to think spatially*. Washington, DC: The National Academies Press.

Oberle, A. P., Joseph, S. A., & May, D. W. (2010). Geospatial technologies as a vehicle for enhancing graduate education and promoting the value of geography. *Journal of Geography in Higher Education, 34*, 475–492. 10.1080/03098265.2010.490907

Rød, J. K., Larsen, W., & Nilsen, E. (2010). Learning geography with GIS: Integrating GIS into upper secondary school geography curricula. *Norwegian Journal of Geography, 64*, 21–35.

Scheepers, D. (2009). GIS in the geography curriculum. *PositionIT*. Retrieved from http://eepublishers.co.za/images/upload/.../GIST-GIS-in-the-geography.pdf

Simsek, A. (2011). The relationship between computer anxiety and computer self-efficacy. *Contemporary Educational Technology, 2*, 177–187.

South Africa Department of Basic Education. (2004). *White paper on e-education* (26734). Pretoria: Government Printers. Retrieved from http://www.education.gov.za/LinkClick.aspx?fileticket=Keu0%2fBkee%2bM%3d&tabid=191&mid=484

South Africa Department of Basic Education. (2011a). *Curriculum and assessment policy statement (CAPS) Geography*. Pretoria: Government Printer. Retrieved from http://www.education.gov.za/LinkClick.aspx?fileticket=50fBP2mS6mk%3D&tabid=420&mid=1216

South Africa Department of Basic Education. (2011b, May). *NEIMS (National Education Infrastructure Management System) reports*. Retrieved June 6, 2015, from https://edulibpretoria.files.wordpress.com/2008/01/school-infrastructure-report-2011.pdf

Wang, Y.-H., & Chen, C.-M. (2013). GIS education in Taiwanese senior high schools: A national survey among geography teachers. *Journal of Geography, 112*, 75–84.

West, B. A. (2003). Student attitudes and the impact of GIS on thinking skills and motivation. *Journal of Geography, 102*, 267–274. 10.1080/00221340308978558